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How the Navy Can Use Open Systems Architecture to Revolutionize Capability Acquisition: The Naval OSA Strategy Can Yield Multiple Benefits

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How the Navy Can Use Open Systems Architecture to Revolutionize Capability Acquisition: The Naval OSA Strategy Can Yield Multiple Benefits[1]

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Introduction

The Department of Defense (DoD) has launched a series of Better Buying Power (BBP) initiatives to acquire dominant capabilities that emphasize technical excellence and innovation (http://bbp.dau.mil). To achieve the goals of BBP, the Navy is applying an Open Systems Architecture (OSA) strategy that promotes open competition, cost control, innovation, and the rapid replacement and upgrade of capabilities to address warfighter needs (Assistant Secretary of the Navy for Research, Development, and Acquisition [ASN(RDA)], 2012). Given the expense of defense acquisition programs—coupled with budget limitations stemming from a fiscally constrained environment—OSA is a timely strategy. This paper describes how the Navy can shift its efforts toward open architectures

[1] The views presented in this paper are those of the authors and do not necessarily represent the views of the DoD or its components.

that can be (1) defined and managed by government/industry consortia and (2) used across multiple air, surface, and/or subsurface platforms, instead of allowing vendors to lock the Navy into proprietary platforms or even contractor-/vendor-specific open architectures.

Limitations With the Status Quo

The Navy has long strived to attain the benefits of OSA approaches. It has historically attempted to achieve open systems by acquiring appropriate data rights and contracting with industry to define an open system based on published and standard interfaces (DoD, 2013). Allowing industry to work in isolation to define system and software architectures, however, has generally locked the Navy into platform-unique solutions or vendor-specific product-lines. These vendor-specific architectures have limited the government's ability to bring third parties into the marketplace to either add new capabilities or compete the role of system integration. This approach has resulted in multiple, disparate, and non-interoperable "open" architectures, which have yielded minimal benefits and often resulted in sole-source or single-bidder contract awards, which negate the benefits of OSA approaches (GAO, 2014).

Toward a Holistic OSA Strategy

Uncoordinated acquisition models to date have limited the promise that can be realized through the systematic application of OSA practices, which require a holistic, strategic approach to maximize benefits. As with other competitive domains, such as the automotive and mobile device domains, the DoD will become more efficient, affordable, and responsive to changes in warfighting demand by applying a product-line–focused acquisition model within and across capabilities, subsystems, and warfighting domains (Guertin & Van Benthem, 2013). Conversely, single-solution acquisition contracts will not provide the long-awaited OSA benefits of affordability, shorter program schedules, and increased warfighting capability. The complexity of advanced warfighting capabilities and their associated safety and security concerns may always make initial delivery lengthy. Significant cost, schedule, and warfighting advantages can be achieved, however, by rapid capability insertion and deployment across a wide installation base—both domestically and internationally.

Experience with OSA approaches in the Navy has shown that investing in the initial design and development of open product-line architectures is needed to reap system life-cycle cost reductions associated with integration, obsolescence, upgrade, and technology refresh (Guertin & Miller, 1998). Benefits to the government can be sustained by OSA through subsequent periodic competition among multiple parties. To ensure these benefits, however, robust and refined intellectual property strategies must be developed to ensure the government acquires what it needs to enable more granular open competition. Likewise, these strategies must also motivate industry to invest in innovation, while simplifying technology refresh across an open system life cycle. These strategies should also incentivize appropriate levels of information sharing and cooperation to avoid common tensions that exist between government program offices and their industry suppliers (Guertin & Reichel, 2014).

Program officials who manage systems that were not initially designed as open architectures have traditionally attempted to break a long-held vendor lock by costly purchases of extra license rights to the technical data. These actions are often applied to address some aspects of the risks associated with competing for the sustainment of the entire system. Those data acquisition strategies have to address an environment in which the Original Equipment Manufacturer (OEM) might have unique technical abilities to understand and maintain the system due to its lack of an open design and its failure to use widely available industry standards and published interfaces ("Vendor Lock-In," n.d.).

In contrast with traditional approaches to breaking vendor lock, a holistic OSA approach starts with central management of shared architectural elements by defining and managing the modules and decomposition of system capabilities. The deployment of these capabilities onto a system is then (1) enabled by the design and development of standardized hardware and software technical reference frameworks and (2) supported by a well-defined intellectual property strategy that facilitates open competition for both product components and integration services. These competitions can be managed in smaller risk-prudent elements and can facilitate capturing innovation arising throughout the defense industrial base.

Using a holistic OSA-based approach to architect future warfighting systems will enable the Navy to address the acquisition of military platforms (e.g., ship, aircraft, submarine, ground vehicle, spacecraft) and the payload systems that go in them (e.g., sensors, command & control, combat, weapons) as separate entities. Integration services can also be established to coordinate both the delivery of systems into the platform and the integration of the components into the payload/mission systems. This comprehensive architectural strategy provides the foundation for a product-line approach across the naval enterprise.

Product-lines are purpose-built to provide different features for different customers within a family of related systems (Software Engineering Institute, n.d.). The product-line concept we propose for the Navy is necessary to ensure that the payload systems employed on multiple platforms are flexible, responsive, and affordable. The warfighter will demand products that are responsive to evolving warfighter capability requirements. The fiscal climate demands that Navy infrastructure costs be kept as low as possible. Since common product-lines share both development and sustainment infrastructure, the wider the array of supported platforms, the greater the cost savings in shared investments (Guertin & Van Benthem, 2013).

The DoD marketplace currently has an array of capable platform integrators and payload system providers. A new approach to system architecture is required, however, to open the DoD market to a greater array of component innovators. Work products that establish payload architectures and platform integration services need to be produced by the government or industry contributors and provided to a new breed of provider—the Capability Integrator Agent—which can be government and/or industry. In general, a holistic approach to architecting defense systems can be applied to help achieve the following benefits of the Navy’s OSA strategy:

1. Eliminate redundant development efforts.
2. Develop flexible and scalable system and software architectures.
3. Tailor deployment of capabilities required to complete a particular mission.
4. Deploy new capabilities to support a range of evolving missions quickly and cost effectively.
5. Increase innovation across the defense industrial base.
6. Avoid or break vendor-lock and improve effective competition.
7. Provide a common framework for international technology transfer agreements.

Elements of a Holistic OSA Strategy and Product-Lines

Achieving the benefits of an OSA strategy outlined above involves a holistic, multi-dimensional, and architecture-driven approach that combines (1) Functional Decomposition, (2) Technical Reference Frameworks, and (3) an Intellectual Property Strategy, as discussed below.

Functional Decomposition

This holistic approach begins with a multi-organization, mission-area engineering team responsible for assigning capabilities that decompose system functionality into components required to execute the mission. One example of this construct is Naval Air Systems Command's (NAVAIR's) Integrated Warfighting Capability (IWC) organization, which established mission-based engineering teams to analyze the "kill chain" and identify the capabilities necessary to execute the mission. The "kill chain" allows the Navy to understand the capabilities necessary to complete the mission and focus investments to those required capabilities. The mission-area engineering team describes the high-level capabilities apart from a specific platform or system in a Mission Technical Baseline (MTB). Next, the team assigns the capabilities to appropriate platforms and systems, which are documented in an Integrated Capability Technical Baseline (ICTB).

A commodity capability program office can then analyze the ICTB in conjunction with a multi-platform portfolio manager who has the necessary insight and authority to develop common capability roadmaps for a portfolio of systems. After achieving a solid understanding of which capabilities have common requirements across systems, these capabilities are further decomposed into discrete core capabilities. The core capabilities serve as the building blocks for developing high-level capabilities. The decomposition of these capabilities includes a description of the capability, the required functionality of the capability, its behavior, and the data interoperability requirements. These descriptions can then be used to develop procurable components that perform the capabilities, which are then deployed on multiple DoD systems.

Technical Reference Frameworks

The second piece of this holistic approach is the development of a limited number of hardware and software Technical Reference Frameworks (TRFs). These standardized frameworks enable the deployment of the functionality and components identified by the Functional Decomposition process described above onto the target architecture, using published and standardized key interfaces. Limiting the number of systematically-aligned TRFs helps maximize component reuse, while minimizing the use of idiosyncratic/product-specific "open" architectures. The Armed Services has already embarked on instantiating these TRFs, including Navy initiatives researching hardware open-systems approaches and the software-reliant Future Airborne Capability Environment (FACE™; n.d.) Standard (Army/Navy).

Intellectual Property Strategy

The last piece of this holistic OSA approach is the adoption of a robust intellectual property (IP) strategy. Standardizing the Technical Reference Frameworks and decomposing/documenting the capabilities needed for a given system provide the acquisition community with increased options for addressing an IP strategy. Previous strategies assumed that acquiring a minimum of Government Purpose Rights (GPR) for the hardware and software within a system would improve the government's ability to compete the product and award to a non-incumbent. This business practice, however, has proven to be insufficient since the resulting systems were not decomposed into discrete components with well-defined, loosely-coupled and highly-cohesive interfaces that correspond to

warfighter capabilities. In practice, these data deliverables are typically a tapestry of different data rights elements, such that demanding GPR has been impractical.

Due to the lack of effective decomposition—along with the “poison pill” of tightly-coupled proprietary elements—the government has historically been limited in the use of delivered data to compete effectively. In particular, monolithic system architectures prevent subsystem upgrades through competition and create a barrier to market entry. This conventional approach presents DoD program managers with few risk-prudent options for competitive upgrades, replacing obsolete capabilities, or improving underperforming systems. It also raises the barrier to entry such that when upgrades are competed, they frequently result in single-bidder responses from the incumbent or ventures that are viewed to be high risk for cost and schedule. This conventional approach not only yields more expensive single-system upgrades, but it also discourages consideration of more capable and innovative solutions.

An IP strategy forms the basis for acquiring the appropriate license rights for technical data that is an integral part of the acquisition strategy. These strategies identify the need to have a well-defined infrastructure and modular architecture because Functional Decomposition provides program managers with the flexibility to add, remove, and replace components as mission capabilities evolve. This flexibility also enables commercial component licensing models, in which it is possible to license an innovative solution and replace it cost effectively when a more capable solution is available or the technology becomes obsolete. Not only do product-line architectures and commercial licensing models leverage innovative solutions from industry, but they also enable the adoption of a more robust and competitive global marketplace.

The products from each dimension of the holistic approach described above form the basis of a flexible, extensible, composable, and scalable system and software architecture for warfighting platforms. These products are described in an Integrated Warfighting Capability Package (IWCP), which can be used by a Lead Capabilities Integrator (LCI) to better manage the system design over the life cycle of the warfighting platform. Figure 1 shows a notional flow for establishing the holistic architecture approach within a DoD acquisition organization.

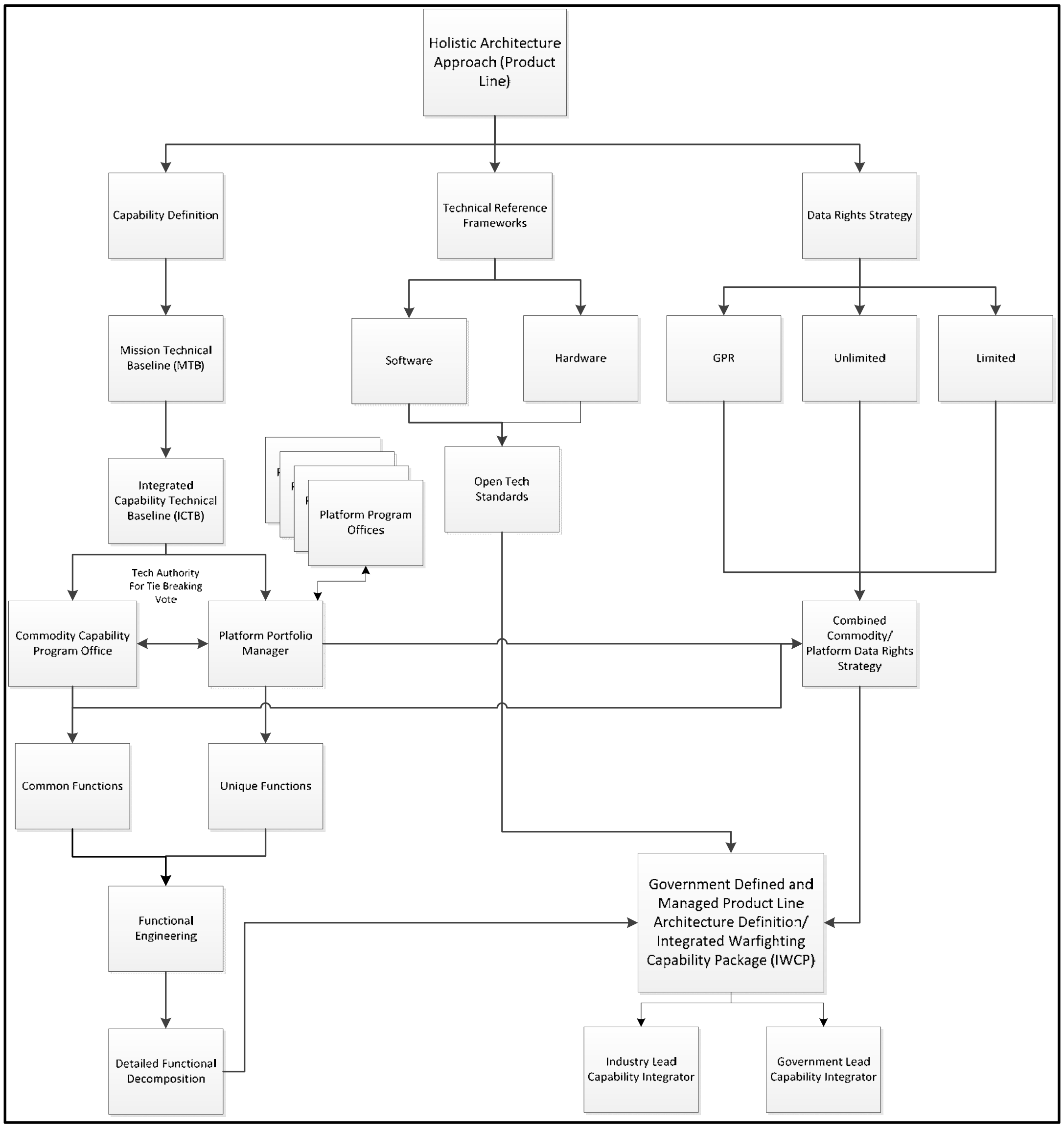

Figure 1. Holistic OSA Flow Diagram

OSA Product-Line Benefits

Establishing a holistic OSA approach that culminates in open capabilities derived as a product-line is not trivial. The end result, however, provides significant value for both the Navy and the warfighter. These benefits will be driven primarily by the consolidation of platform-unique architectures into an open product-line architecture defined and managed by government/industry consortia that will enable the following benefits:

1. Common capabilities to be reusable across multiple platforms
2. Common training for installation, operation, and maintenance
3. Competition throughout the life cycle for components of payload systems
4. Competition throughout the life cycle for integration services (including assignment of government labs in selected instances)
5. Competition throughout the life cycle to deal with obsolescence, upgrades, and maintenance

6. Consolidation of government development and test lab infrastructure
7. Markets that are currently vendor locked to be opened (foreign and domestic)
8. The science and technology community to focus on innovative capabilities
9. The international cooperation initiatives to focus on innovative capabilities
10. Improved commercial data rights licensing strategies
11. Consolidation of contract actions for redundant capability
12. The ability to integrate emerging capabilities affordably
13. Cross-Service common capability reuse and interoperability
14. International common capability reuse and interoperability

These benefits are crucial to sustaining the warfighting dominance of the United States and its allies. In the present fiscal environment, the acquisition community must make a cultural shift away from sole-source, platform-unique solutions and adopt a holistic OSA approach to deliver the most capability across the DoD, preserving the relevance—and effectiveness—of the warfighter.

OSA Product-Line Challenges

Several leadership challenges exist in establishing a holistic OSA approach and instantiating a capability-based product-line, as discussed in this section.

Culture Shift

The hardest challenge to overcome is the significant acquisition and organizational cultural shift that must occur within the defense acquisition community (Guertin & Clements, 2010). This community has historically focused on single-platform solutions, which results in stove-piped acquisitions (Schmidt, 2013). Organizational processes need to shift to focus on the capabilities needed to perform a mission and which of those capabilities are common across multiple platforms. Program managers and acquisition leadership will need to accept and manage a shared risk across programs to reap significant cost avoidance with minimal schedule or performance risk.

Financial Leadership

Another challenge is coordinating the funding sources needed to mature the product-line architectures that embody Technical Reference Frameworks. Classic accountability methods of single program managers having autonomy over stove-piped products will not suffice to establish shared design environments, testing, infrastructure and life-cycle support. The challenges in evolving to a set of common and shared set of foundation elements will need to be resolved:

- Segregated accountability—If an independent capability program office is used, production funding for the platform instantiation will be isolated. This could segregate accountability of the capability from the integrating platforms. This segregation may lead to a perceived restriction of technical and financial trade space over a single program office authority, but better enable multi-platform trade space decisions for common capabilities.
- Restrictive platform reuse—If the development of the product-line architecture is tied to an early adopting program, the lead platform will maintain perceived trade space. The platform requirements of the early adopting program may heavily influence or bias the common-capability architecture requirements,

however, resulting in an overly restrictive solution that hinders systematic reuse since it does not meet the requirements of other platforms.

Despite these potential drawbacks, the Navy cannot afford "business as usual," which is the development of vendor-unique stove-piped architectures. These stove-piped architectures lock programs into a small number of system integrators, each devising proprietary point solutions that are expensive to develop and sustain over the life cycle. Resource sponsors, commodity capability program managers, and platform portfolio managers should therefore work together to strategically coordinate investments that ensure maturation of product-line architectures that are suitable to their domains. This coordination will allow the mitigation of shared risk, thereby ensuring that programs are successful, relevant, and sustainable well into the future.

Workforce Education and Training

Another key challenge is developing an acquisition workforce with the right knowledge, skills, and abilities (KSAs) to manage a holistic product-line approach. Today's cultural focus and acquisition alignment is designed to accommodate platform-unique solutions, where each system brings its own networks, computers, displays, software, and operators. The Navy therefore needs to increase its skill set to architect, design, develop, and maintain each of the pillars of this holistic approach.

The Navy also needs to train personnel in all career fields with skills related to software and hardware product-line management, including program managers, portfolio managers, architects, engineers, logisticians, test engineers, contract managers, and data-rights specialists. Moreover, the Navy may need to reach into the defense industrial base to recruit the workforce with the necessary KSAs to help influence the current organizational culture by providing valuable insight and lessons learned for establishing and maintaining product-lines.

International Technology Transfer Program

The DoD is not the only national defense organization attempting to benefit from the instantiation of OSA in its respective organization. Alignment of OSA strategies across allied nations could benefit existing and future technology transfer agreements by allowing the sharing of innovative technologies between nations more affordably and effectively.

The DoD's International Science and Technology Engagement Strategy (DoD, 2014) seeks to enhance interoperability and collaboration with allied nations through the exchange of innovative technologies. Its ultimate goal is to accelerate research and development programs and leverage emerging global opportunities to enhance the capabilities of the United States and its allied partners while gaining economic efficiencies. Applying a product-line approach among allied nations could allow international partners to quickly and affordably reach the goals of the international engagement strategy.

Alignment of a product-line architecture approach is already underway through the Technology Transfer Cooperative Program (TTCP; n.d.) between the United States, Canada, United Kingdom, Australia, and New Zealand. Through multinational collaboration and coordinated investment within the TTCP Aerospace Systems Group (AER) Technical Panel 7 (TP-7), a standardized approach to mission systems OSA is being developed. Once this alignment has matured, other allied nations' technology transfer groups and organizations can utilize the agreed-upon product-line architecture to affordably and rapidly develop, integrate, and test new technologies, while ensuring multinational integration and interoperability.

Emerging and Ongoing OSA Efforts

Several OSA efforts are ongoing throughout the DoD, including hardware open system approaches, the FACE™ standard, Joint Common Architecture (JCA), Unmanned Aerial System (UAS) Control Segment (UCS), and TTCP. The benefits of the holistic approach to OSA discussed above can be enhanced and accelerated by harmonizing these efforts and collectively mandating their adoption in acquisition programs. By leveraging efforts already underway and coordinating investments across services and allied nations, enterprise-wide product-lines can be established.

The hardware open system approaches being pursued by NAVAIR and Georgia Tech Research Institute (GTRI) are intended to provide requirements and guidance for developing open hardware computing systems for hardened military use. Their approach's core tenets promote upgradeability, expandability, sustainability, and component reuse. A joint NAVAIR and Army Aviation influenced effort is the FACE™ Technical Standard and corresponding business practices. The FACE™ initiative establishes a technical and business ecosystem to enable open software architectures, software portability and reuse, and easy software integration efforts, resulting in decreased costs and fielding schedules for DoD software aviation capabilities.

The Army's Joint Common Architecture (JCA) is defining and describing the low-level Functional Decomposition to be incorporated into future Army helicopter programs. These capabilities would be deployed on the FACE™ architecture as building blocks in a manner that forms the capabilities necessary to execute the Army's mission threads.

The Office of the Secretary of Defense has commissioned the UCS Technical Society to design and document a standardized functional decomposition of UAS Control Segment (UCS) services. The UCS functional decomposition standard will be used to develop and deploy modular capabilities onto control stations based on the mission needs of the UAS that is being controlled. The UCS-defined modular ground station capabilities have been deployed on a FACE™-enabled architecture during a recent airborne demonstration, showcasing the feasibility of a holistic architecture approach.

The international alignment efforts being performed under the TTCP organization will take the current OSA efforts from each of the partner nations and align them to develop a common architectural approach, enabling development of technologies in collaboration with member nations. Likewise, NAVAIR has championed a true cultural shift in strategic thinking by establishing a mission-level engineering organization, the IWC, to analyze and define the kill chain. This analysis is being used to flow capability-based requirements down to the commodity and platform programs for acquisition. NAVAIR has also embraced several of the other OSA efforts, which have begun to pull together a holistic approach to OSA by strategically linking these efforts with the mission engineering organization to establish and mature a product-line architecture for use on future naval aviation platforms. Through this cultural shift, NAVAIR is advantageously positioning itself to realize the benefits of the holistic approach in the future.

Concluding Remarks

When applied properly, OSA practices can increase affordability and reduce time to field, while providing increased capability to the warfighter. A holistic approach to OSA using functional decompositions of common functionality, standardized hardware and software technical reference frameworks, and a cohesive data rights strategy will yield these benefits. Also crucial to a holistic OSA approach are government/industry consortia, which help

incentivize the appropriate levels of information sharing, cooperation, and standardization necessary to ensure a "win-win" solution.

The Navy can reap significant benefits by realigning its investments to establish, mature, and maintain the pillars of product-lines and Technical Reference Frameworks. While this realignment may initially seem daunting, pockets of success are appearing, which can be leveraged and combined to form a holistic architecture strategy across the naval enterprise. Although the challenges of cultural change are significant, the benefits of future technological and financial efficiencies far outweigh the risks and costs of maintaining the current acquisition status quo.

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